

# **Status of a NASA Standard and Three NASA Handbooks**

Dennis L. Kern  
Jet Propulsion Laboratory, California Institute of Technology  
Pasadena, California

## **ABSTRACT**

NASA-STD-7003 *Pyroshock Test Criteria*, May 18, 1999, has been revised per direction of NASA Headquarters to make it a mandatory standard and to update it for advances in the discipline since its initial release. NASA-HDBK-7004B *Force Limited Vibration Testing*, January 31, 2003, and NASA-HDBK-7005 *Dynamic Environmental Criteria*, March 13, 2001, are being updated to reflect advances in the disciplines since their last release. Additionally, a new NASA handbook, NASA-HDBK-7008 *Spacecraft Structural Dynamics Testing* is currently being prepared. This paper provides an overview of each document, summarizes the major revisions for the documents undergoing update, and provides the development schedules.

**KEY WORDS:** Spacecraft, dynamic environmental criteria, vibration testing, pyroshock testing, standards, NASA

## **INTRODUCTION**

In the early 1990's the NASA Office of Chief Engineer implemented a program to develop NASA-wide standards to provide uniform engineering and technical requirements for processes, procedures, practices, and methods employed for selection, application, design, and test criteria for spaceflight hardware. In addition, the program developed NASA handbooks to encourage the use of best practices and to support consistent treatment of engineering issues across the Agency. NASA is now making some of the standards mandatory for all NASA flight hardware projects and the NASA handbooks are being updated to reflect advances in the technology. The Jet Propulsion Laboratory (JPL) is the lead center for one of the standards and three handbooks relating to dynamics environments criteria and testing. These documents are currently undergoing development or revision: a) NASA-STD-7003 *Pyroshock Test Criteria* is undergoing revision to make it mandatory for NASA projects per NASA direction and updating for advances in the technology, b) NASA-HDBK-7004B *Force Limited Vibration Testing* and NASA-HDBK-7005 *Dynamic Environmental Criteria* are being updated to reflect technology advances and add new material, and c) NASA-HDBK-7008 *Spacecraft Structural Dynamics Testing* is a new handbook that captures recent advances in spacecraft level structural and environmental dynamics testing. An overview of the contents, major revisions, and development schedules for each of the four documents are provided.

## **NASA-STD-7003A *Pyroshock Test Criteria***

The contents of NASA-STD-7003 includes subjects such as a) definition and description of the pyroshock environment, b) definition of the maximum expected flight environment (MEFE), c) test margins, methods, and facilities, d) state of the art data acquisition and analysis methods, e)

prediction methods for pyrotechnic shock, and f) preferred methods for determination of the MEFE. Numerous changes have been made for 7003A to incorporate pyroshock technology advances, improve the clarity of the information, update technical references, make definitions compatible with IEST and MIL-STD-810G pyroshock standards, and most importantly to conform to the NASA template for mandatory standards. The current 7003A draft includes 18 mandatory or “shall” statements, some with multiple parts. The “shall” statements represent minimum requirements for NASA flight projects. The “shall” statements are summarized in the section 1.6 of the standard and are repeated below:

## **1.6 Summary of Pyroshock Test Criteria**

A summary of the mandatory requirements is given in this section. Mandatory pyroshock test margins are summarized in table 1. Specific pyroshock test requirements are selected based on the following:

- a. The flight or service pyroshock environment as defined in section 3.2.3.
- b. The environment test categories described in section 3.2.5.
- c. The level of assembly defined in section 3.2.6.
- d. The maximum expected flight environment as specified in section 4.2.
- e. Test margins as discussed in section 4.3.
- f. Test specifications described in section 4.4.
- g. The test method and facility as outlined in section 4.5.

**1.6.1** If there is a serious question about the hardware susceptibility to pyroshock, then pyroshock testing shall be performed.

**Table 1—Summary of Pyroshock Test Margins**

Pyroshock Type	Qualification	Protoflight	Flight Acceptance
Self-Induced/Actual Device	2 Actuations	2 Actuations	1 Actuation
Externally-Induced/Simulated	MEFE + 3 dB 2x Each Axis	MEFE + 3 dB 1x Each Axis	MEFE 1x Each Axis

**1.6.2** Pyroshock verification shall be accomplished experimentally.

**1.6.2.1** Pyroshock testing shall be considered essential to mission success.

**1.6.3** Pyrotechnic test criteria shall be based upon the MEFE or service environment.

**1.6.4** When statistical analysis is selected, it shall be based on P95/50 statistics of shock response spectrum (SRS) data.

**1.6.5** Pyroshock Qual testing for externally-induced pyroshock environments shall be performed with a magnitude margin added to the MEFE to account for failure due to hardware variability.

**1.6.5.1** A minimum qual margin of 3 dB shall be added to the MEFE uniformly across the spectrum (or  $1.4 \times \text{MEFE}$ ).

**1.6.6** A minimum of two shock applications per axis for externally-induced shock environments shall be applied for pyroshock Qual testing.

**1.6.7** When performed, FA testing for externally-induced shock environments shall be conducted at MEFE conditions with one shock application per axis.

**1.6.8** Protoflight (PF) testing for externally-induced shock environments shall be performed at Qual magnitude (or  $1.4 \times \text{MEFE}$ ) with one application per axis.

**1.6.9** For Qual and PF testing for self-induced shocks, a minimum of two firings of the flight pyrotechnic devices shall be performed for those devices that generate the dominant pyroshock environment for potentially sensitive equipment.

**1.6.10** For devices that do not generate the dominant pyroshock environment for potentially sensitive equipment, the pyrotechnic devices shall be fired once to verify that they do not generate a more severe shock condition for any potentially susceptible hardware.

**1.6.11** When FA testing is performed for self-induced shocks, one firing of the flight pyrotechnic devices shall be performed for those devices that generate the dominant pyroshock environment for potentially sensitive equipment.

**1.6.12** System-level pyrotechnic device test firings shall be adequately instrumented to verify assembly level requirements.

**1.6.13** Pyroshock tests to simulate externally-induced environments shall be specified using maximax SRS with a constant quality factor of  $Q=10$ , based on the MEFE described in section 4.2 and a margin described in section 4.3, and over a natural frequency range consistent with the appropriate pyroshock environment (i.e. near, mid, or far-field) as defined in section 4.4.

**1.6.14** The pyroshock test to simulate externally-induced environments shall achieve the required SRS within the tolerances specified in section 4.8 for three-orthogonal axes.

**1.6.15** The pyroshock test waveform or time history shall have similar oscillatory characteristics to that of the predicted flight event with a total duration similar to that of the predicted flight event and no longer than 20 ms.

**1.6.16** If pyroshock-sensitive hardware is located so that it is exposed to the near-field environment, near-field testing shall be required.

**1.6.17** Before analog-to-digital conversion (ADC), anti-aliasing filters shall be applied to the analog signals.

**1.6.18** The tolerances most commonly used in current aerospace practice are specified for the maximax SRS and shall be used:

<u>Natural Frequency</u>	<u>Tolerance</u>
$f_n \leq 3 \text{ kHz}$	$\pm 6 \text{ dB}$
$f_n > 3 \text{ kHz}$	$+9/-6 \text{ dB}$

**1.6.18.1** The SRS shall be calculated with a resolution of at least one-sixth (1/6) octave band for the natural frequency range of the test specification.

**1.6.18.2** At least 50 percent of the SRS magnitudes shall exceed the nominal test specification.

**1.6.18.3** The acceleration time-history used to create the SRS for the laboratory pyroshock simulation shall be preserved for comparison to the flight acceleration time-history.

Dr. Vesta Bateman (Sandia National Laboratories, retired), was a consultant on the development of NASA-STD-7003A and performed the majority of the rewrite effort. Currently, the draft standard has undergone two NASA peer reviews with pyroshock experts from most of the NASA Centers taking part. A consensus draft of the revised standard was submitted for Agency review in July 2010. The Agency review, completed in December 2010, resulted in 107 comments and recommended changes. Resolution of the comments/recommended changes to the consensus draft NASA-STD-7003A should be completed by the 26<sup>th</sup> ATS and the revised standard ready for Agency release.

### **NASA-HDBK-7004C *Force Limited Vibration Testing***

NASA-HDBK-7004B provides force limited vibration test criteria, including force limiting rationale, instrumentation, fixtures, specifications, control systems, test planning considerations. It also provides force limiting implementation details such as methods to derive force limits, the concept of effective mass, and methods to determine effective mass. It also evaluates the appropriateness of force limiting criteria based on flight and ground test data. Finally, it provides examples force limited vibration testing criteria derivations.

NASA-HDBK-7004C is being reorganized and rewritten to improve clarity. Significant non-editorial changes have also been made to date:

1. Three guidelines have been added on the application of force limiting that provide a) a minimum test article Q value to justify the use of force limiting, b) appropriate rationale for deriving  $C^2$  values, and c) criteria to avoid excessive notching.

2. The methods for deriving force limiting have been updated: the semi-empirical method and quasi-static loads criteria have been substantially revised, an impedance method is new, and the TDFS method and the related spreadsheets have been removed from the handbook.

3. Added a case history on the GLAST spacecraft ground vibration test and flight data.

Dr. Terry Scharton, JPL, retired, and original author of NASA-HDBK-7004, performed the updates to the handbook. The draft 7004C will be distributed for peer review by March of this year and should be approved by NASA before the end of the 2011.

### **NASA-HDBK-7005A *Dynamic Environmental Criteria***

The scope of NASA-HDBK-7005 encompasses a) the dynamics environments a spacecraft may be exposed to over its mission life, b) the state-of-the-art procedures for predicting the dynamic excitations (i.e., loads) produced by the dynamic environments, c) the state-of-the-art procedures for predicting the structural responses to the dynamic excitations, d) the state-of-the-art procedures for establishing dynamic criteria with appropriate margins for the design and testing of a spacecraft and its components, and e) the equipment and procedures used to test a spacecraft and its components. The original publication of the 7005 handbook is 235 pages and required an intensive effort to compile, not only by the five authors, but also through contributions and reviews from numerous dynamics experts in NASA, other government agencies, and industry.

NASA-HDBK-7005 is being revised to improve the clarity in some areas and to update and expand the handbook for advances in the state-of-the-art. Some of the updates that are underway or have been identified include the following:

1. Improved pyroshock test simulation and data acquisition techniques as have been incorporated in NASA-STD-7003A.
2. The status of analytical pyroshock prediction methods under development.
3. Advances in force limited vibration testing, which is currently barely mentioned in 7005.
4. Expanded discussion of mobility methods for dynamics problems.
5. Advances in Statistical Energy Analysis (SEA), Boundary Element Analysis, and numerical methods for high frequency (above 50 Hz) predictions of dynamic excitations and structural responses
6. Techniques to account for end-to-end uncertainties in vibroacoustic predictions.
7. Improved techniques to account for component mass loading effects in vibroacoustic predictions.
8. Improvements in prediction of vibration responses due to aerodynamic fluctuating pressures.
9. The impact of extreme peaks in random dynamic environments.

## 10. Advantages and disadvantages of direct field (loudspeakers) acoustic testing.

Several individuals have already made significant contributions to the update of the handbook. These include Dr. Ali Kolaini, JPL, Dr. Vesta Bateman, and Dr. Terry Scharton. Dr. Sheldon Rubin, Rubin Engineering Company (also, The Aerospace Corporation, retired) and Dr. Jerry Manning, Cambridge Collaborative, Inc., both among the original coauthors of NASA-HDBK-7005, have agreed to participate in the update. It is anticipated that a draft 7005A will be available for peer review in August 2011, assuming timely continuation funding is provided.

### **NASA-HDBK-7008, *Spacecraft Structural Dynamics Testing***

NASA-HDBK-7008 is a new handbook that addresses structural dynamics testing of flight spacecraft and large instruments, and associated dynamic test models and flight structure subsystems for the mission dynamics environments and loads. The handbook concentrates on new dynamics testing methodologies, but summarizes and provides key references for older dynamic and static test methodologies. Dynamics tests addressed include: a) base drive and stinger vibration (sine, random, and transient), b) acoustics (reverberant chamber and direct field, i.e., loudspeakers), c) pyro firings, and d) combined dynamics tests. Major topics covered include test description, test purpose, test program, test planning, test implementation, interpretation of test results, and case histories.

NASA-HDBK-7008 is being developed in collaboration with Dr. Terry Scharton and with Mr. Scott Gordon, NASA Goddard Space Flight Center. The draft handbook will be distributed for peer review by April of this year and should be approved by NASA before the end of 2011.

### **ACKNOWLEDGMENT**

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

### **BIOGRAPHY**

Mr. Dennis Kern has worked in vibration, acoustic and shock prediction and testing for aerospace structures and components for 39 years. He has supervised the dynamics environments activities at the Jet Propulsion Laboratory since 1978, supporting all JPL flight projects and managing numerous technology development programs. Mr. Kern has played a major role in the development of several NASA and industry standards and handbooks and has co-organized the annual NASA/USAF/Industry Spacecraft and Launch Vehicle Dynamics Environments Workshops since 1988. He holds BS and MS degrees in Mechanical Engineering from California State University Long Beach.